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KINETIC ENERGY WEAPON DIGITAL EMULATION CENTER

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Abstract

The Kinetic Energy Weapon Digital Emulation Center (KDEC) located at the U.S. Army Strategic Defense Command in Huntsville, Alabama is an analysis center supporting the evaluation of new and evolving Kinetic Energy Weapon (KEW) technologies and interceptors. KDEC serves as both an experiment test bed and a data center. As an experiment center KDEC provides the KEW community with an environment conducive to simulation development and test analysis by providing users a simulation framework and validated KEW interceptor models to aid in development and analysis. As a data center KDEC provides a central repository for simulations, emulations, data and other information of interest to the KEW community and the SDIO. This paper presents an overview of the KDEC role as both an SDIO data repository and an experiment test bed.

Background

The KDEC provides the required tools and technical expertise to support the evaluation and validation of the new and evolving KEW interceptors and technologies. The KDEC was developed as an analysis center to be able to quickly and cost effectively develop an interceptor simulation and to provide the appropriate environments and threats to support one-on-few testing. To support this mission KDEC was developed with a KEW data repository which includes both interceptor ground and flight test data, a government owned six degree of freedom KDEC Simulation framework (KSIM), and the KDEC Digital Emulation Framework (KDEF). The KDEC also provides technical analysts who have the expertise to design, evaluate and validate the KEW simulations. The end products that KDEC produces are verified and validated simulations utilizing the data available in the data repository along with the KDEC developed tools, KSIM and KDEF. Figure 1 illustrates the four major functions of KDEC which are described in the following paragraphs.

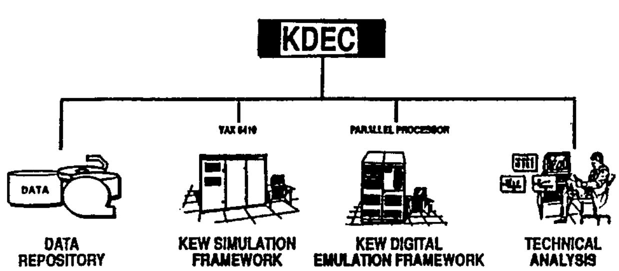

Figure 1. KDEC Functions

The KDEC Data Repository

The KDEC Data Repository is supported by an advanced automated card catalog system and configuration management tool suite for KEW technology items, hereafter referred to as KEW data products. These computerized tools are called the Data Repository Catalog System (DRCS). Data products are stored in computerized and hard-copy repositories in the KDEC facility located in the U.S. Army Strategic Defense Command's Simulation Center. The combination of the computerized and hard-copy repositories comprise the KDEC Data Repository, and include the following elements:

A. Computer Software
  - simulations
  - emulations
  - data reduction, conversion, and editing tools
  - simulation data analysis tools
  - test bed subsystem and component models

B. Data
  - flight and ground test data at various levels of refinement
  - simulation input and output data
  - analyses of simulation data

C. Documentation
  - KEW component models and algorithms
  - computer software design documentation
  - computer software user documentation
  - technical reports.

A single data product may be made up of one or many of the elements listed above. As is true with a card catalog system for any large library, the card catalog portion of the DRCS provides detailed descriptions of the data products in the repository and serves as an index to the elements in the repository. However, the DRCS catalog system contains much more comprehensive detail than is typically found in book library card catalogs. This descriptive detail for the data product is referred to as the "characterization" for the data product. Data product characterizations include details of what the data product is, what its constituent elements are, how these elements interrelate, where these elements reside in the computerized and hardcopy libraries, etc.

A multi-level hierarchical decomposition scheme is used to characterize data products. The levels in hierarchical order are: data product, sub-system, component, object and object element. In general, this hierarchy means that a data product is composed of multiple sub-systems, a sub-system is composed of multiple components, and so on. This hierarchical decomposition scheme provides an effective mechanism for describing and organizing the constituent elements of a data product. The DRCS maintains data base records describing each element within the data product element hierarchy.

The DRCS offers a set of automated configuration management facilities to support a wide range of configuration control and configuration status accounting activities. The following functions are provided:

- data product submission, release/distribution, and check-in requests
- KDEC service requests
- deficiency reports
- engineering change proposals
- KDEC user authorization
- KDEC access monitoring and control
- configuration management activity reporting.

The DRCS provides a multi-window, user friendly graphical interface to display a data product (e.g., the loading of some technical document in a text display window) or to activate a data product for execution on a KDEC computer (e.g., the start-up of a data analysis tool). This interface provides the KDEC analyst with a convenient, "seamless bridge" to step from the process of perusing catalog records to the processing of a selected data product with some display or data analysis tool, or to execute the data product within a simulation analysis environment.

The DRCS was implemented using Ingres/Windows 4GL, a powerful fourth generation language development environment. This visual programming environment greatly accelerates the development of windows/forms based applications which interact with the Ingres Relational Data Base Management System. A character based version of the DRCS has been developed which provides the same functionality of the Windows 4GL based application, but without the more advanced graphics display features. This character based version is used to support the remote, dial-up user of KDEC, and was implemented using Ingres Applications-by-Forms (ABF). The Windows 4GL based DRCS is impractical for remote access due to its graphics intensive operations. The character based version of the DRCS does not have the performance limitations of the Windows 4GL application when accessed remotely over a telephone line.

Three powerful record search mechanisms are available in the DRCS. The search types are selection from index, query by keyword, and the graphical SDIO context query.

The selection from index capability involves the simple selection of a catalog record from a scrollable display in alphabetic order. Two scrollable lists are presented on a screen. One scrollable list contains an alphabetized master list of all records for one of the hierarchical levels chosen. The other list displays a list of the records selected from the master list. Items are selected from the master list by highlighting a desired record and clicking a mouse button. For any highlighted record in the master list, a mouse activated button on the display form is used to display a record abstract which appears in a pop-up window. When the user has filled the selected records list with all desired records, an execute query button is activated to retrieve full record detail. An example of the select from index query screen is given in Figure 2.

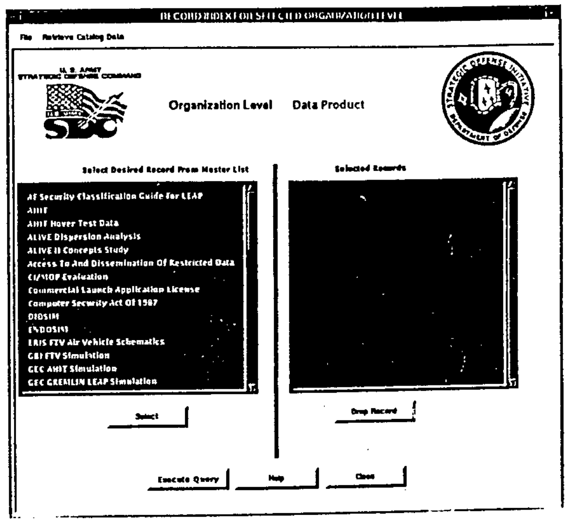

Figure 2. Example of the Select from Index DRCS Screen

The query by keyword capability operates in a manner very similar to the selection from index capability. The first scrollable list here contains an alphabetized list of all keywords. An example of this screen is given in Figure 3.

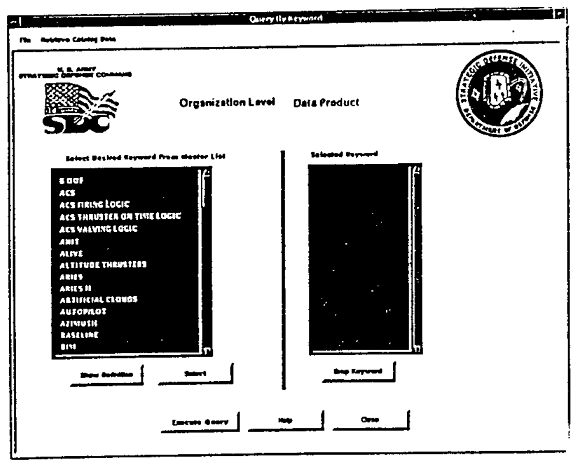

Figure 3. Example of the Query by Keyword DRCS Screen

The graphical SDIO context query facility provides a highly intuitive, easy to use graphical interface to select data product catalog records based on the particular aspect of strategic defense which they support. On the Context Query by Graphics screen, selectable graphical icons are presented against a background picture which enhances the "intuitiveness" of query construction. The background picture displays a screen of the flight path of an intercontinental ballistic missile. A portion of the globe is displayed on the bottom part of the screen. This arc is labeled with four mouse selectable buttons: BOOST PHASE, POST BOOST PHASE, MIDCOURSE PHASE, and TERMINAL PHASE.

One of the attributes of a data product is its applicability to a particular phase of a threat, so when one of these phase icons is selected, all data products dealing with that phase are selected. Selectable icons on the screen use a special color to differentiate a selected status from a non-selected status.

Another screen facility exists to help the user further narrow the record selection scope. A "box" in the lower right hand corner presents a list of individually selectable data product types to which a search may be restricted (e.g., simulations, technical reports, engineering data sets, etc.).

The final selectable elements for this screen are the individual buttons which display pictures of various strategic defense elements. If the right mouse button is clicked when the cursor is on one of these icons, all data products within the category represented by the icon will be selected. If the left button is "clicked", a pop up display of additional graphical icon buttons will appear, each of which represents a subcategory within the parent category. An example of the SDIO Context Query by Graphics screen is presented in Figure 4. An example of this screen with a set of visible subcategories for the Exo-Atmospheric Interceptor category is given in Figure 5.

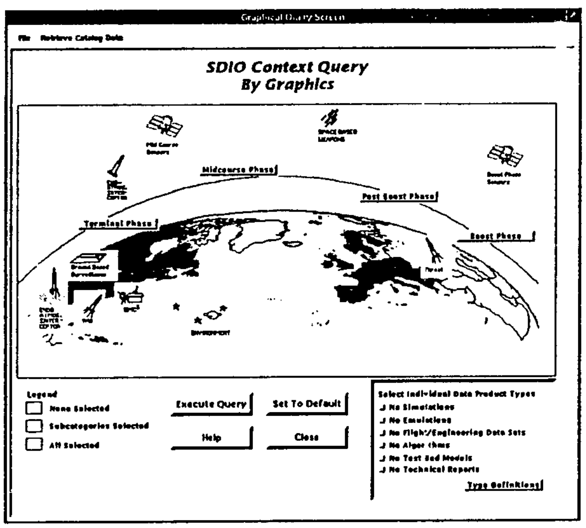

Figure 4. Example of the SDIO Context Query by Graphics DRCS Screen

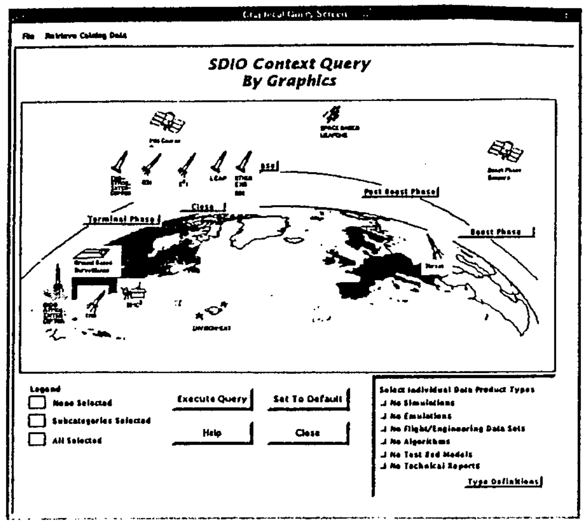

Figure 5. Example of the SDIO Context Query by Graphics Screen with Sub-Category Icons Displayed

The KDEC program eventually plans to introduce scanning and optical character recognition technology, and an optical disk juke box management system to facilitate high volume KEW data product storage.

KDEC Simulation Framework

The KDEC Simulation Framework (KSIM) provides a government owned six degree of freedom simulation development environment. KSIM dramatically enhances simulation development productivity by providing an environment for creating new, advanced end-to-end interceptor simulations from high-level software building blocks rather than writing new simulation programs line by line.

This non-real-time simulation framework is used for the testing of KEW elements, sub-systems, and components in a high fidelity simulation testbed. KSIM includes a core simulation driver library, a library of generic, commonly used mathematical routines, and a reusable missile component model library. The core simulation driver provides Strategic Defense Initiative Organization approved nuclear and natural environments and threat models which offer standardized engagement scenarios.

KSIM based simulations, also referred to as test articles, are constructed by piecing together high level software building blocks from the libraries of validated, well engineered and tested Ada software components. To develop highly reusable software with the characteristics of high quality, reliability, and maintainability, considerable attention must be given to the use of modern software engineering methods. KSIM software library components have been and will continue to be developed under DoD-STD-2167A, the military standard for building defense system software.

To achieve a high degree of software reusability, KSIM software has been designed using object oriented analysis and design principles, particularly those defined by leading Ada software design expert Grady Booch. Software components designed for KSIM are closely scrutinized by a team of experienced Ada software engineers to ensure that modern software engineering principles are embodied in the design, especially the characteristics of abstraction, encapsulation, and information hiding. Extensive use of Ada generics is made in order to further enhance the degree of reusability.

To assist the simulation analyst building a new simulation from KSIM library software components, a "Test Article Developer's Guide" has been developed. This document provides a guide to configuring and interfacing existing software components to create new end-to-end interceptor simulations.

A significant pre-planned product improvement for KSIM is scheduled which will further enhance ease of use and productivity of new test article development. This improvement involves the development of a graphical user interface to support rapid test article construction.

Using this graphical interface, new simulation programs would be generated by "point-and-click" operations with a mouse on a series of interceptor block diagrams. For example, clicking on a generic diagram of a seeker housing would precipitate the appearance of a pop-up window containing an alphabetized, scrollable list of seeker technology types. Clicking on an individual item in this window would prompt another window to appear containing an alphabetized, scrollable list of specific seeker models in the Ada software components library. The analyst would make a seeker model selection, then proceed to select the remaining elements of the test article until fully configured.

Early experience with KSIM indicates that this development environment can reduce the time required to build advanced, end-to-end interceptor simulations by over 60 percent, with less than half the staff required compared to traditional methods for building these simulations. Again, the reason for this is that KSIM based simulations are built from pre-tested, well engineered high level building blocks. This approach dramatically reduces the amount of new code to be developed for any new simulation.

Figure 6 illustrates the phenomenal technical and economic potential which KSIM offers when contrasted with traditional simulation development methods.

- DETAILED SIMULATIONS TYPICALLY COST $1.5 M AND REQUIRE 18 MONTHS TO DEVELOP
- KSIM REDUCES THIS COST TO $200K AND REQUIRES ONLY 6 MONTHS

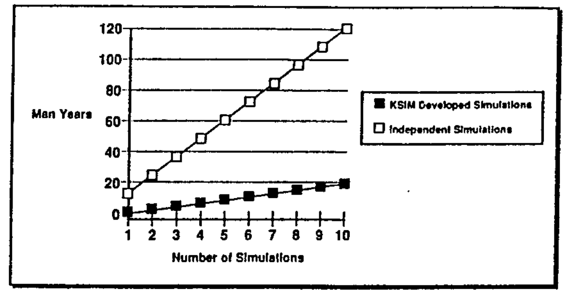

Figure 6. KSIM and Development Productivity

The KSIM is synergistically complemented by the DRCS, which provides a quick means to validate developing simulations with real data from actual flight and ground tests. The KDEC workstations provide high resolution, multi-window displays which allow for the simultaneous viewing and processing of multiple software applications.

The KSIM analyst is supported with an advanced pre-processing tool. The pre-processing tool is, like the DRCS, an Ingres/Windows 4GL application and offers the same kind of user friendly graphical interface.

The primary function of the pre-processor is to provide for initialization of a test article's variables, and for specifying which variables are to be output on a permanent file and under what conditions (i.e., simulation program states) they are to be output during simulation program execution. Any number of unique sets of program variable initializations, hereafter referred to as "experiments", may be developed with the pre-processor for a given test article. The individual program variable initial values and output designations for an experiment are stored in and kept under configuration control using the Ingres Relational Data Base Management System.

Once a test article has been constructed within the KSIM environment, the test article may be executed in a mode which creates a Test Article Cross Reference File. This Test Article Cross Reference File contains descriptions about the test article's program variables. The pre-processor provides a Test Article Cross Reference File Editor which allows the analyst to do such things as establish default values for a variable, write a narrative description for the variable, and set the specification of upper and lower bounds for the variable. All of this information is retained in relational tables maintained by the Ingres Relational Data Base Management System.

The pre-processor also provides an Experiment Editor, which allows the analyst to establish individual variations of the test article's baseline or default values. When creating an experiment, an analyst may choose to override a default value for a variable as initially established with the test article Editor. The analyst may also create any number of unique variable output specifications. The pre-processor also provides a facility to initiate and control the execution of an individual experiment.

The pre-processor provides the same kinds of convenience features as seen in the DRCS. For example, to select a test article variable for some purpose, the analyst uses a scrollable window containing a list of the test article's variables in alphabetic order. For a highlighed variable name item in the list, a button may be clicked which creates a pop-up window displaying a descriptive abstract of the variable. Such features greatly improve the analyst's productivity and reliability during the tedious process of initializing large, complex simulations. Figure 7 provides an example of a pre-processor screen.

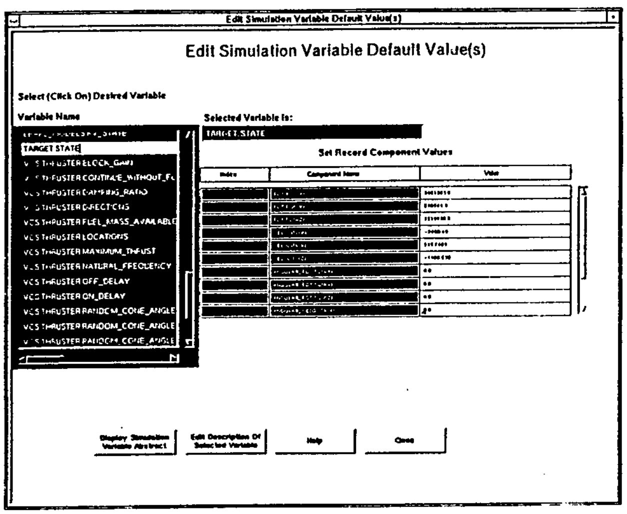

Figure 7. Example of a Pre-Processor Screen

In order to make the KSIM a fully government owned software system, a character based (non-graphical) version of the pre-processor will soon be available. This program is being written in Ada, and provides the same fundamental functions as found in the Windows 4 GL based application.

KSIM provides an Ada based post-processor which executes in a character based environment. This post-processor is used by the analyst to generate output specifications for output data created by an executing KSIM simulation. Output specifications are kept in computer files and may be later retrieved and edited.

KSIM output data may be formatted using the post-processor so that it is compatible with a number of commercial-off-the-shelf data analysis and visualization tools, including PV~WAVE and several major spreadsheet packages. In addition, it is capable of formatting simulation output data for use with a fully government owned data plotting and analysis tool developed under the KDEC program. This tool is called the Generic Evaluation Capability (GEC), and is a C language based program which runs in an X-Windows environment.

Figure 8 provides an overview of how the KDEC analyst uses KSIM tools to develop new test articles, create experiments, and format output data for later analysis. These activities are performed from a single KDEC workstation.

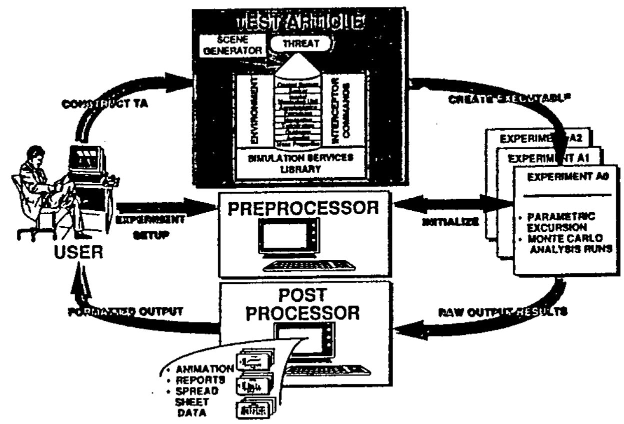

Figure 8. KSIM Testbed Overview

The KDEC program has also developed an animation generation program which reads a simulation output file and produces a realistic looking graphical presentation of the simulated flight. This animation program is written in the C language, runs on a Silicon Graphics workstation, and utilizes Silicon Graphics specific graphics software. Although originally written to provide an animation of an early LEAP missile flight, the program can be tailored to provide animations for other missile simulations.

KDEC Digital Emulation Framework

The KDEC program has been researching alternatives to providing a real-time digital emulation framework for test and evaluation of KEW hardware and software designs at KDEC and other SDIO KEW centers. No definite plans for the emulation architecture have been defined at the time of this writing, but several key engineering capability requirements have been established.

A formost requirement for the KDEC Digital Emulation Framework (KDEF) is to provide a completely faithful model of missile system interfaces. In other words, the behavior of individual components of an emulation and the communications between these components should be indistinguishable from the actual hardware components. A significant implication of this requirement is that the KDEF should be able to communicate across a variety of hardware interfaces (e.g., analog signals, A/D, D/A, buses, etc.) found in real missile systems.

From the practical standpoint of software development, the KDEF architecture should support direct, easily traceable relationships between models developed in the non-real-time KSIM environment, and the corresponding models which run in a real-time, multiprocessing environment. This requirement in turn places a significant burden on the use of effective, modern software engineering techniques. A readily traceable, smooth migration of non-real-time simulation software to a real-time multiprocessor environment is possible only with well designed, modular software components with well engineered interfaces which precisely follow real world interfaces found in missile system componentry. The ability to change component models without reconfiguration is a desirable end result from a sound software engineering process.

Several desirable characteristics have been identified for the KDEF which have significant effects upon emulation development productivity and cost. A list of such desirable qualities includes:

- the ability to accomodate multiple users during the development and debugging phases
- the ability to run the emulation end-to-end, with quick, smooth transitions between flight phases
- source level debuggers which work in a parallel processing environment (Ada, Fortran, and C)
- interrupt response hardware faithfully models hardware and software interrupts
- performance monitoring tools
- task control of communications connectivity (dynamic message routing capability)

Technical Analysis

The KDEC staff includes personnel who have technical expertise in both simulation development and providing KEW flight test pre and post mission analysis. The KDEC staff also includes personnel who have the responsibility to train KDEC users. This training includes both how to use the data repository and also how to develop test articles to fit into the KSIM framework.

In the past year KDEC staff have been extensively involved in supporting the Lightweight Exoatmospheric Projectile Program (LEAP) with flight test analysis. This support has included developing simulations to support both the LEAP hover testing which has taken place at the National Hover Test Facility (NHTF) at Edwards Air Force Base and the LEAP flight tests which will be conducted from White Sands Missile Range. The simulations developed for the hover testing were used for safety volume analysis and have been validated utilizing the resulting hover data.

The validated hover simulations were then incorporated into the KSIM framework to provide an end-to-end flight test capability. The KDEC staff have performed multiple Monte Carlo sweeps using this simulation to support boost phase, midcourse and end-game analysis of the LEAP flight test. This LEAP flight simulation has provided very :ble pre flight analysis.

After the LEAP 1 flight test, the data from the test will be stored in the KDEC data repository and will be used by the KDEC staff to validate the LEAP simulation. The validated LEAP 1 simulation will provide a verification point for the LEAP 2 and LEAP 3 simulations. This is a very cost effective way for the government to develop and validate simulations and also to provide the needed pre and post mission analysis that is required to reduce risk in flight tests. The end result of the KDEC effort for LEAP is to provide traceable validated simulations of the LEAPs utilizing the ground and flight test data.

Summary

The KDEC facility is both an SDIO data center and experiment test bed. As a data center KDEC provides access for the SDIO community to the KEW ground and test flight data through the DRCS. As an experiment center KDEC includes KSIM, KDEF, and technical analysts to provide a one-on-few test capability for endo, exo and space based interceptors. All of the KDEC tools and data repository were developed according to DoD-STD-2167A and have been fully documented.

The KDEC is scheduled to reach Full Operational Capability (FOC) in the fourth quarter of FY92. At FOC KDEC will include baseline endo, exo and space based interceptors which will be available for analysis of interceptor performance and technology insertion. The KDEC provides a high detailed validated one-on-few testbed capability which can be used to reduce risk in the interceptor flight tests. As the KDEC tools mature and the data repository expands, the development productivity for simulations and emulations will increase. This reduces costs by providing reusable Ada software, and at the same time providing the government with an efficient simulation validation process.